# Refinement of the contamination formation mechanism in the pneumatic transporting system of a cotton harvester using a new U-shaped receiving chamber

*Rafik* Matchanov[1], *Abdurakhim* Yuldashev[2], *Davronbek* Kuldoshev[2*], and *Nargiza* Djuraeva[2]

[1]JV "Agrikhim", Tashkent, Uzbekistan
[2]Institute of Mechanics and Seismic Stability of Structures of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

**Abstract.** The relevance of reducing raw cotton contamination during machine harvesting is substantiated in this article. The morphological composition of impurity elements in raw cotton, obtained during years of experience, is given; it shows that fine trash amounts to 63.93% -75.1% and is difficult to clean when processing cotton. The experimental results of a new U-shaped receiving chamber are presented, which confirm the reduction of contamination of raw cotton by up to 30% compared to serial receiving chambers. Mathematical models are presented for calculating the contamination of raw cotton using a U-shaped receiving chamber. The mechanism of impurity saturation of raw cotton during its transport in the pipes of the pneumatic transport system of the cotton harvester is substantiated. A comparison of the calculated data on the contamination of raw cotton with the experimental data obtained using a new U-shaped receiving chamber showed that the error limit is 4.8÷9.1%.

## 1 Introduction

When harvesting raw cotton by machines, reducing cotton contamination is one of the important tasks in the field of the ginning industry. This is due to the fact that with high contamination during primary processing, additional processing is required, which in turn leads to an increase in costs in the raw cotton processing, and a decrease in fiber quality due to an increase in the number of short fibers.

Depending on the quality of the resulting fiber, single, double, and triple cleaning is used. Many scientists dealt with the issues of fiber cleaning [1-11]and reducing the contamination of raw cotton during machine harvesting [12-22].

As is well known, it is difficult to clean fine trash that penetrates into the fiber. Therefore, when harvesting by machines, a necessary condition is to minimize the content of fine trash in the morphological composition of impurity elements. Based on the results of many years

* Corresponding author: don_02@mail.ru

of experience obtained by the SAIME and SAMIS organizations, changes in the morphological composition of impurity elements during machine harvesting of raw cotton are shown in Table 1 [22].

**Table 1.** Raw cotton contamination during machine harvesting by morphological composition, obtained in different years, %.

| Morphological composition | SAMIS, 1987 | SAIME, 1988 | SAIME, 1989 | SAIME, 1990 |
|---|---|---|---|---|
| Stalks | 0.13±0.07 | 0.122±0.05 | 0.115±0.08 | 0.108±0.08 |
| Hulls | 13.63±3.67 | 16.6±4.55 | 21.34±8.94 | 12.3±2.52 |
| Leaf stalks | 9.42±2.03 | 8.36±1.24 | 8.32±1.93 | 7.38±1.40 |
| Branches | 12.25±4.20 | 1.42±0.30 | 1.64±1.52 | 1.17±1.27 |
| Seed-buds | - | 1.3±0.46 | 0.88±0.67 | 1.37±1.13 |
| Flowers | - | 0.653±0.28 | 0.37±0.43 | 0.763±0.74 |
| Weeds | - | 1.83±0.81 | 1.94±1.64 | 1.05±0.79 |
| Soil | 1.01±0.85 | 0.672±0.96 | 0.743±0.82 | 1.05±0.86 |
| Fine trash | 63.93±7.54 | 68.9±5.67 | 64.65±12.9 | 75.1±4.8 |

Analysis of data in Table 1 shows that in the morphological composition of impurity elements, a significant proportion is made up of the trash, which varies within 63.93÷75.1%.

The results of experimental studies conducted by the authors [23] to determine the mechanism of contamination formation during machine harvesting by vertical-spindle machines (17XVtype) are shown in Table 2.

**Table 2.** Raw cotton contamination samples in different zones (according to A.I. Komogortseva).

| Morphological composition | Working area | Transporting corridor | Hopper |
|---|---|---|---|
| Stalks | 0.12 | 1.29 | 0.94 |
| Branches | 0.01 | 0.05 | 0.03 |
| Stalks and stalks leaves | 0.36 | 0.85 | 0.82 |
| Dry leaf, flowers | 0.59 | 1.26 | 0.84 |
| Bass | 0.00 | 0.01 | 0.02 |
| Fine trash | 2.05 | 2.98 | 4.46 |
| Soil | 0.00 | 0.01 | 0.00 |
| Seed buds | 0.08 | 0.25 | 0.42 |
| Weeds | 0.95 | 0.34 | 0.50 |
| Total | 4.16 | 7.04 | 8.03 |

The analysis of Table 2 shows that fine trash in the zone of the transporting corridor of the harvester makes up 2.98%, and in the hopper, it amounts to 4.46%. However, the authors did not establish the reasons for the saturation of raw cotton with trash, starting from the transporting corridor of the harvester and ending with the hopper.

The aim of the study – refinement of the mechanism of saturation of raw cotton with fine trash in the pneumatic transport system of the cotton harvester using a new U-shaped receiving chamber.

## 2 Methods

Experimental and numerical studies of the contamination of raw cotton using a new U-shaped receiving chamber.

## 3 Results

A new U-shaped receiving chamber (Figure 1) was developed [24-26] to eliminate the shortcomings of the serial slit-like receiving chamber.

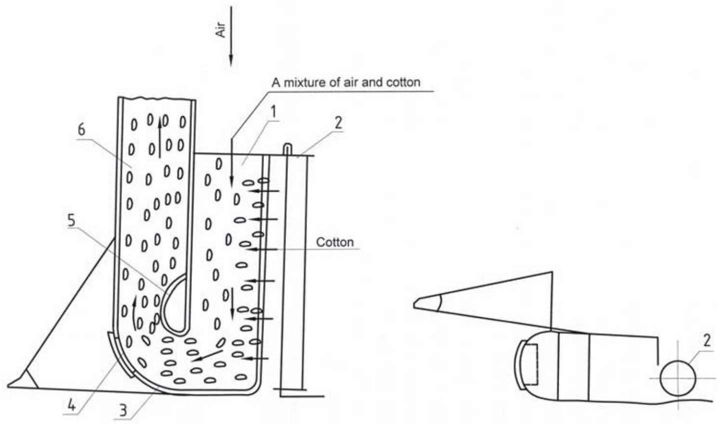



**Fig.1.** New U- shaped receiving chamber.

The receiving chamber consists of the vertical inlet pipe 1 with a side slit-like opening for receiving cotton mass, equal in height to bar 2 of the doffer; curved bottom 3 connecting vertical inlet pipe 1 with outlet pipe 6, a window with lid 4 to remove, if necessary, solid impurities, fairing 5 for directing the air-cotton mixture with less resistance to outlet pipe 6 connected to the suction line of the fan.

In order to reduce local resistance in the system, the sections of the receiving chamber 1, the discharge pipe 6 and the lower part of the transition zone of the curved bottom 3 are made the same.

Transportation of raw cotton in the receiving chamber is carried out as follows. During the operation of the harvesting machine, the cotton collected by the spindles is thrown by the doffers into the receiving pipe 1, then the cotton lobules move from top to bottom of the receiving chamber with the suction air flow, while the airflow increases its velocity and reaches its maximum value in the lower part of the receiving chamber, where the cotton falls on the curved bottom 3, then the airflow moves the cotton at maximum velocity through the outlet pipe 6 to the suction line of the fan and, further, to the hopper of the cotton harvester. Ensuring the maximum velocity of the airflow in the lower part of the receiving chamber eliminates the clogging of the receiving chamber with cotton.

In connection with this, field tests of cotton harvesters were conducted using serial and new receiving chambers (Figures 2, a, b).

(a) (b)

**Fig. 2.** Vertical spindle machines with serial (a) and new (b) receiving chambers.

The conditions for conducting laboratory and field tests are presented in Table 3. The results of the field tests are given in Table 4.

**Table 3.** Conditions for conducting laboratory and field tests.

| Name of indicators | Values of indicators | |
|---|---|---|
| | toATT | According to test data |
| 1 | 2 | 3 |
| Test date | | 22.10.2020 |
| Test site | | Yangiyul district Test site CITT |
| Pretreatment | | Cotton defoliation |
| Crop | | Cotton |
| Variety | - | C-6524 |
| Row spacing, cm | - | 90 |
| Plant height, cm | 80-120 | 100 |
| Plant width, cm | No data | 40 |
| Number of fruit branches per 1 plant, pcs. Total | - | 8 |
| including: - monopodium | - | 1 |
| - sympodium | - | 7 |
| The number of bolls on 1 plant, pcs. Total | No data | 9 |
| including: - open bolls | -//- | 8 |
| - semi-open bolls | -//- | - |
| - closed bolls | -//- | 1 |
| The number of seed buds on 1 plant, pcs. | | None |
| Percentage of opened bolls, % | No less than 80-90 | 90 |
| The number of leaves on 1 plant, total, pcs. | - | - |
| including: - green leaves | No more than 3 | 2 |
| - dry leaves | No more than 4 | 2 |
| Plant density, pcs/ha | No data | 99 703 |
| Height of the bottom boll, cm | No less than 8 | 25 |
| Row spacing, cm: | | |
| - basic | - | 90 |
| - end | - | 98 |
| Depth of irrigation furrows, cm | - | 17 |
| Raw cotton yield, c/ha | - | 28.0 |
| Humidity of raw cotton on stalks, % | No more than 11 | 6.6 |

**Table 4.** Field test results.

| Indices | Serial receiving chamber | | | New U-shaped receiving chamber | | |
|---|---|---|---|---|---|---|
| Working slit width (mm) | 30-28 | 32-28 | 34-28 | 30-28 | 32-28 | 34-28 |
| Cotton moisture content, % | 8.9 | 7.6 | 9.5 | 7.2 | 7.4 | 8.2 |
| Cotton contamination, % | 13.9 | 11.2 | 11.5 | 10.9 | 10.2 | 10.0 |
| Crushing of cotton seeds, % | 0.2 | 1.0 | 0.2 | 0.4 | 0.4 | 0.21 |

The data in Table 4 show that using a new receiving chamber, the contamination of raw cotton is less compared to the serial chamber. Based on this, it is possible to analyze the process of saturation of raw cotton with trash, starting from the transporting corridor of the harvester and ending with the hopper.

It is known that there are three types of velocities of motion of an air-cotton mixture: air flow velocity (V), velocity of the material (Vm) and air velocity relative to the material or soaring speed (Vs). The soaring velocity is determined by the following formula:

$$V_s = V - V_m$$

The soaring velocity of impurity elements in raw cotton has been well-studied by the authors [25]. By experimental studies, it was determined that the soaring velocity of a stretched lobule is 4.69-5.35 m/s, of an open cotton boll - 7.96-9.62 m/s and of a pappus - 2.3-3.75 m/s. The saturation of raw cotton with trash in the pneumatic transport system (PTS), when conveyed through pipelines, is explained by the fact that the velocity of small trash particles is higher than that of cotton lobules. For example, at an airflow rate of $\vartheta_{\text{в}} = 20$m/s, the velocity of small trash particles is $\vartheta_{\text{c}} = 19$m/s, and the velocity of raw cotton lobules is $\vartheta_{\partial} = 15$m/s [25]. If the length of the PTS is taken as $\ell = 4.5$m, then the time for the cotton lobules to pass from the receiving chamber to the hopper is:

$$t_x = \frac{4{,}5}{15} = 0.3 \quad sek$$

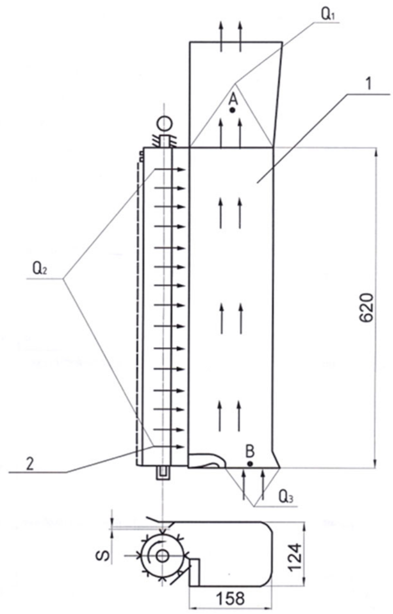
The time for small trash particles to pass from the receiving chamber to the hopper is:

$$t_c = \frac{4{,}5}{19} = 0.23 sek$$

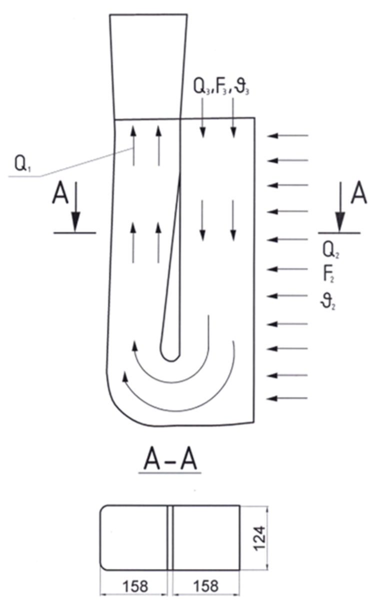
The calculation results showed that small trash particles, which pass the length l = 4.5 m faster than cotton lobules, collide with raw cotton particles in the process of motion, and then raw cotton with trash and dust particles, moving inside the pipeline, is thrown into the hopper of the cotton harvester (Figure 3).

**Fig. 3.** Separation of dust particles in the hopper of a cotton harvester.

The air-cotton mixture, after exiting the pipelines, collides with the cellular surface of the hopper cover separator. At that, light fractions of free fine trash and dust are removed through the separator, and fine trash combined with the cotton falls into the hopper. The process of contamination formation in the pneumatic transport system of a vertical-spindle cotton harvester [23] showed that the soaring velocities of trash particles and cotton lobules differ. The following calculation method is presented to explain the reduction in cotton contamination when using the new U-shaped receiving chamber. Figure 4 shows the distribution of air volume in the serial (a) and new (b) receiving chambers.




(a)




(b)

**Fig. 4.** Distribution of the volume of draw-in air in the serial receiving chamber (a), and in the new U-shaped receiving chamber (b).

The balance of air volume distribution is:

$$Q_1 = Q_2 + Q_3, \text{ m}^3/\text{s} \quad (1)$$

The concentration of trash particles in terms of the volume of draw-in air in the serial ($Q_1$) and new U-shaped receiving chambers ($Q_2$) is assumed to be the same (Figure 3).

In the new U-shaped receiving chamber clean air is sucked insection $F_3$. In section $F_2$, the contaminated air-cotton mixture is sucked in. We determine sections $F_2$ and $F_3$ according to the drawings, $b$ is the gap for the raw cotton passage between the ends of the brush and the wall; $н$ is the doffer height; $a$ is the width of the receiving chamber; $b$ is the length of the receiving chamber:

$$F_2 = b \cdot н = 0.07 \cdot 0.62 = 0.0434\text{m}^2,$$
$$F_3 = a \cdot b = 0.124 \cdot 0.158 = 0.0195\text{m}^2,$$
$$F_2 + F_3 = 0.0434 \cdot 0.0195 = 0.0629\text{m}^2.$$

Next, we determine $Q_2$, taking into account the change in the concentration of trash particles over the cross-section of the intake of clean ($F_3$) and contaminated ($F_2$) air:

$$Q_2 = \frac{F_2 \cdot Q_1}{F_2 + F_3} = \frac{0.0434 \cdot Q_1}{0.0629} = 0.69 \cdot Q_1, \text{m}^3/\text{s} \tag{2}$$

However, depending on the concentration of the air-cotton mixture ($\mu$), the ratio $\vartheta_2$:$\vartheta_3$changes. Based on the experimental data, we accept the coefficient as

$$K^{'} = \frac{\vartheta_2}{\vartheta_3} = 1.0 \div 1.2.$$

With coefficient$K^{'}$, expression (2) can be rewritten in the following form:

$$Q_2 = 0.69 \cdot Q_1 \cdot K^{'}, \text{m}^3/\text{s} \tag{3}$$

For a serial receiving chamber with an intake air capacity ($Q_1$), the contamination of raw cotton is ($S_0$).

Based on the equality of the concentration of trash particles, the contamination of raw cotton when using a new receiving chamber is determined by the following formula:

$$S_x = \frac{S_0 \cdot Q_2}{Q1} = \frac{S_0 \cdot 0.69 \cdot Q_1 \cdot K^{'}}{Q1} = S_0 \cdot 0.69 \cdot K^{'} \tag{4}$$

## 4 Discussion

Data from Table 4 obtained as a result of laboratory and field tests show that with a working slit width of 30-28 mm, the contamination of the raw cotton harvested by machines with serial receiving chambers is $S_0$=13.9%, and with new receiving chambers, it is $S_x$=10.9%. Using expression (4), we determine the estimated contamination of raw cotton $S_x$.

According to the experiment, we accept$K^{'}$=1.2, then:

$$S_x = S_0 \cdot 0.69 \cdot K^{'} = 13.9 \cdot 0.69 \cdot 1.2 = 11.51\%$$

The difference in the experimental and calculated data is:

$$\Delta S_x = |10.9 - 11.51| = 0.61\%$$

With a working slit width of 32-28 mm, the difference in the experimental and calculated data is:

$$\Delta S_x = |10.2 - 11.2 \cdot 0.69 \cdot 1.2| = 0.93\%$$

With a working slit of 34-28 mm, this difference is:

$$\Delta S_x = |10.0 - 11.5 \cdot 0.69 \cdot 1.2| = 0.48\%$$

Analyzing data from Table 4, we see that the use of a new U-shaped receiving chamber can reduce the contamination of raw cotton by 30% compared to a serial receiving chamber. Numerical studies of cotton contamination using a new U-shaped receiving chamber showed a slight deviation in the calculated and experimental data - 0.48 ÷ 0.93%, so, the error limit is 4.8 ÷ 9.1%.

## 5 Conclusion

The mechanism of contamination formation in the pneumatic transport system of the cotton harvester was refined, which makes it possible to determine the difference between the velocities of small trash particles and cotton lobules.

The use of a new U-shaped receiving chamber provides a reduction in the contamination of raw cotton by up to 30% compared to serial ones due to a decrease in the concentration of trash particles in 1 $m^3$ of clean sucked-in air.

## References

1. R.D. Matchanov, *Cotton pickers 1929-2010* (Tashkent, 2011)
2. J-Sh. Tian, X-Yi Zhang, W-F. Zhang, J-F Li et al, J. of Integrative Agr. **17(5)**, 1120-1127.
3. A.A. Rizaev, *Research and creation of working bodies of a cotton picker with high efficiency* (Tashkent, Fan, 2017)
4. A.D. Abdazimov, S.S. Radjabov, N.N. Omonov, J. of Phys.: Conf. Ser. **1260(3)**, 032001 (2019). https://www.doi.org/10.1088/1742-6596/1260/3/032001
5. K. Turanov, A. Abdazimov, M. Shaumarova, S. Siddikov, Advances in Intelligent Systems and Computing **1258**, 290-305 (2021). https://www.doi.org/10.1007/978-3-030-57450-5_27
6. P.A. Ntogkoulis, D.D. Bochtis, Bi-osystems Engineering **119**, 25-34 (2014)
7. A. Abdazimov, E. Uljaev, N. Omonov, S. Radjabov, The advanced science journal **12**, 49-51 (2014)
8. Y.G. Ampatzidis, S.G. Vougioukas et al, Biosystems Engineering **120**, 25-33 (2014)
9. D.M. Mukhammadiev, Kh.A. Akhmedov, O.Kh. Abzoirov, O.S. Mallaev, N.B. Esanova, J. of Phys.: Conf. Ser. **1889**, 042019 (2021). https://www.doi.org/10.1088/1742-6596/1889/4/042019
10. A.A. Drai, V.I. Balabanov, The technology of mechanized cotton harvesting using the MX-1,8 cotton harvesting machine, Bulletin **6**, 7-11 (2015)
11. A.A. Rizaev, R.G. Makhkamov, A.T. Yuldashev, O.S. Norkuziev, Problems of Mechanics **1**, 44-48 (2013)
12. T. Li, F. Hao et al, Transactions of the Chinese Society for Agricultural Machinery **49(s1)**, 233-238 (2018). https://www.doi.org/10.6041 /j.issn.1000-1298.2018.S0.031
13. J. Tian, X. Zhang et al, Industrial Crops and Products **107**, 211-216 (2017)
14. A.N. Abdullaev, *Development of an interrelated model for assessing the contamination of raw cotton and the productivity of machines with horizontal-spindle devices*: Dis. … Cand. Tech. Sci. (Yangiyul, 2004)
15. K.D. Baker, C.D. Delhom, S.E. Hughs, American Society of Agricultural and Biological Engineers Journal (2017). https://www.doi.org/10.13031/aea.10991
16. A.D. Glushchenko, A.A. Rizaev, A.T. Yuldashev, D.A. Kuldoshev, Problems of mechanics **5-6**, 11-35 (2009)
17. K.D. Baker, S.E. Hughs, J. Foulk, American Society of Agricultural and Biological Engineers Journal (2015). https://www.doi.org/10.13031/aea.31.10687
18. R.D. Matchanov, *Cotton pickers 1929-2010* (Tashkent, 2011) 66-75

19. G. Bahadirov et al, IOP Conf. Series: Materials Science and Engineering **1030** 012160 (2021). https://www.doi.org/10.1088/1757-899X/1030/1/012160
20. Sh.T. Ravutov, Problems of Mechanics **4** (2019)
21. M. Shoumarova, T. Abdillayev, B. Sarimsakov, Sh. Yusupov, IOP Conf. Series: Materials Science and Engineering **883**, 012099 (2020). https://www.doi.org/10.1088/1757-899X/883/1/012099
22. D.B. Alimova, *Modeling of the apparatus of a cotton harvester and their working organs* Republican Scientific and Technical Conference **206-13** (2021)
23. Khabibulla Turanov, Mukhaya Shaumarova, E3S Web of Conferences **164**, 06034 (2020). https://www.doi.org/10.1051/e3sconf/202016406034
24. N.S. Otajonov, R.D. Matchanov, A.T. Yuldashev, A.A. Rizaev, Z.M. Malikov, R.R. Khudaykuliev, D.A. Kuldoshev, Patent No. IAP 06981 dated June 27, 2022 (published in Bulletin No. 7 on July 29, 2022). Method of transporting raw cotton from the receiving chamber to the hopper of the cotton harvester and a device for its implementation (2022)
25. A.A. Rizaev, Z.M. Malikov, A.T. Yuldashev, D. Kuldoshev, D.A. Temirov, A.N. Borotov, IOP Conf. Series: Materials Science and Engineering **1030**, 012175 (2021). https://www.doi.org/10.1088/1757-899X/1030/1/012175
26. R.D. Matchanov, A.A. Rizaev, A.T. Yuldashev, D.A. Kuldoshev, M.M. Mirzaeva, E3S Web of Conferences **264**, 04011 (2021). https://www.doi.org/10.1051/e3sconf/202126404011
27. Z.M. Malikov, R.D. Matchanov, A.I. Yuldashev, N.B. Djuraeva, E3S Web of Conferences **264**, 01014 (2021). https://www.doi.org/10.1051/e3sconf/202126401014